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A Determination of the Normal Variations in Count and Strength in Woollen Yarns

By
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A Determination of the Normal Variations in Count and Strength in Woollen Yarns

by W. J. HALL.

Introduction.

Large samples of woollen yarns representing everyday commercial practice have been tested for count and strength with a view to finding the magnitude of the variations. These variations have been compared with those found in earlier experiments in which it was possible to take small samples only. Typical sets of results have been analysed in detail and the variations in weight across the condenser have been recorded. These examples indicate clearly the necessity of a regular examination in which all the ends delivered by the condenser are weighed separately. In this way much light can be thrown on the causes of irregularity in the web made by the carder and in the rovings delivered by the condenser.

It should be noted that the experiments have to do with hanks, and that *local* irregularities (twits, etc.) are not dealt with except so far as they affect the average strength. Such local irregularities may of course be very serious and visible in a cloth, etc., but this paper shows that even the variation of average count from cop to cop amount to from 20% to 50% and, as already stated, the importance of testing all the ends occasionally cannot be exaggerated.

Summary and Conclusions.

The variations found in the course of this work are surprisingly large, but since every care has been taken during the testing under specially controlled conditions, these variations must be accepted as real. Doubtless many practical men will protest that they make yarns less variable than the samples in this paper. The only reply is to insist that the samples are truly representative and were taken from ordinary everyday practice in the mills.

The work points to the following conclusions :—

(1) The average coefficient of variation of weight* or count is about $4\frac{1}{2}$% (*i.e.*, an average variation of $4\frac{1}{2}$% above or below the average count). For very regular yarn the coefficient may fall to about 3% whilst for irregular yarn it may rise to nearly 6%. The extreme variations, however, are very much greater. Reference to Table A shows that the greatest count exceeds the least by about 20% as a rule, but may exceed it by 50%. There is obviously room for improvement even in the best yarns.

*For explanation see appendix.

(2) The coefficients calculated from the results of the tests on large samples agree with those from the small samples in the earlier experiments. Representative results for the variation may therefore be obtained from samples consisting of 12 spinning cops if these are evenly distributed across the condenser.

Whilst 12 cops are enough for ordinary purposes, it should be noted that an individual bad thread may easily be missed, *e.g.*, a thread from a slack or spreaded tape, or thin ends near the side of the condenser.

(3) As a test of the regularity of the slubbings made by a carder and condenser, it is advisable to take a complete set of tests occasionally, the position of each thread on the condenser bobbin and mule being noted. For this purpose it is not necessary to spin more than is required (say 100 yards) for the actual hanks to be weighed and pulled.

(4) It should be noted that hank tests on a considerable length of yarn have been made. The inch by inch variations are much larger and may show more in a cloth. Their determination will form the subject of a separate study. Publication No. 48 shows that yarns are graded in about the same general order by the hank test and the single thread test.

Reasons for carrying out the tests.

The work in the present paper arose out of that described in Publications No. 36 and No. 44. The yarns from various types of carding engines working parcels from the same blends were then tested for strength and count and from the individual tests the coefficients of variation of strength and count were calculated. These coefficients were a measure of the irregularity of the yarns.

Now the conditions under which these earlier experiments were performed did not admit of the application of the tests to large samples. The question therefore arose as to whether the tests on the small samples yielded results which were truly representative of the bulk. In order to get strictly comparable results, the samples taken from the several spinners' yarns were as nearly as possible of the same size and the testing was done under conditions specially chosen to prevent the entry of other variables.

There are no published figures giving the variations in strength and count which are always found when tests are made on a number of cops or bobbins from the same batch of yarn. As a criterion, for the purpose of judging the results of the experiments on carding and spinning about to be put in hand at Torridon such information will be required, so that our work may be accurately compared with commercial practice.

After a discussion of the subject it was decided to collect and test larger samples of yarn in order to find the magnitude of the *variations normally occurring*. The samples were taken from *ordinary daily production* in the mills by the courtesy of a number of members.

Collection and Testing of Samples of Yarn.

The sizes of the samples vary according to the number of spindles in the mule. The condenser bobbins were marked as they were taken from the carding engine and the spinning was commenced as soon as there were sufficient bobbins to fill the mule. The cops or bobbins of yarn were numbered as they were removed from the spindles. It was thus possible to tell exactly on which ring or tape of the condenser the slubbing, from which the yarn was spun, was made, and also the position on the mule.

The testing of the samples is described in detail in Publication No. 36. A Goodbrand hank tester (motor driven) was employed and one test was made from each cop. The hanks were weighed on an automatic balance designed at Torridon, its accuracy being about one part in 500. Previous to testing, each sample was stored in the humidity room at a constant relative humidity of 70% and at a temperature of 72°F., as moisture has a considerable effect on tests of wool.

The hank test was employed on account of its convenience. The comparison between the hank test and the single thread test is dealt with in Publication No. 48. With the hank test a reasonable amount of material may be tested in a short time. This work would have been impossible if it had been necessary to rely on the single thread test.

The Results of the Tests.

Table A presents in a concise form the whole of the results. The first column gives the constitution of the carding engine with the types of intermediate feed and condenser. The size of the sample of yarn is indicated in the column showing the number of spindles. In addition to the nominal count, the actual average and also the greatest and least counts are recorded. The average, greatest and least strengths are included as a matter of considerable interest, and as measures of variation, the coefficients of variation of weight and strength.

Weight of Hank

The coefficient of variation of weight of a hank is given as it is just as useful as that of the count and is more easily calculated. In fact, if the counts are calculated from the weights, and their coefficient of variation is found, the difference between it and the coefficient of variation of weight will be negligible.

Table A.

Machine	No. of Spindles	Firm	Blend	Nominal Count	Average Count	Least Count	Greatest Count	No. of Yds. in bank	Average Strength	Least Strength	Greatest Strength	**Weight Coeff. of variation**	**Strength Coeff. of variation**
								(1 yd. per turn)	lbs.	lbs.	lbs.		
Breast and 2 Swifts, Scotch Feed, Breast and 2 Swifts, Series Tape Condenser, 96 threads	480	A	50 cotton	18 sk.	17.13	15.42	22.90	72	103.44	60	140	**4.97%**	**11.31%**
Breast and 2 Swifts, Scotch Feed, 2 Swifts, Endless Tape Condenser, 100 threads	300† 300	B	About 46's Crossbred	16 sk.	16.31 16.06	15.00 14.75	19.43 19.11	64	57.61 61.43	38 42	70 75	**4.22%** **4.09%**	**8.35%** **7.96%**
Breast and 4 Swifts, Scotch Feed, 2 Swifts, Series Tape Condenser, 112 threads	420	C	Merino	30 sk.	26.65	22.17	29.90	60	60.27	51	73.5	**4.15%**	**5.86%**
5 Small Swifts, Scotch Feed, 2 Swifts, Double Ring Doffers, 96 threads	304	D	Shoddy All Wool	18 sk.	18.40	16.32	21.24	72	64.94	48	86	**4.11%**	**10.24%**
Breast and 2 Swifts, Scotch Feed, 2 Swifts, Single Ring Doffer, 50 threads	300	E	Crossbred	14 sk.	13.77	12.40	15.26	56	63.08	50	78	**3.55%**	**7.97%**
Breast and 2 Swifts, Scotch Feed, Breast and 2 Swifts, Double Ring Doffers, 52 threads	312	F	46's Crossbred	16 sk.	15.00	12.24	17.53	64	104.46	85	136	**5.92%**	**8.25%**

† In order to prove the validity of the figures obtained in this method of testing, a second test was taken from each of the 300 bobbins constituting the sample firm B. The coefficients calculated from the second tests are in good agreement with those from the first set.

TABLE A (*continued*).

Machine	No. of Spindles	Firm	Blend	Nominal Count	Average Count	Least Count	Greatest Count	No. of Yds. in hank	Average Strength	Least Strength	Greatest Strength	**Weight Coeff. of variation**	**Strength Coeff. of variation**
2 Swifts, Diagonal Feed, 1 Swift, Scotch Feed, 1 Swift Series Tape Condenser, 116 threads	464	G	Crossbred	14 sk.	14.26	12.27	16.00	56	66.17	53	90	**4.20%**	**8.35%**
Breast and 1 Swift, Ball Feed, 1 Swift, Single Ring Doffer, 60 threads	Direct 360 Spun	H	Merino	36 cut 28.10 sk.	34.70 ct. 27.08 sk.	31.90 ct. 24.94 sk.	37.40 ct. 29.20 sk.	56	47.03	39	54.5	**2.93%**	**5.72%**
Ditto.	360 Drawn and Spun	H	Merino	36 cut 28.10 sk.	35.12.ct. 27.46 sk.	30.50 ct. 23.86 sk.	40.20 ct. 31.40 sk.	56	46.68	38.5	56.5	**3.65%**	**6.16%**
2 Swifts, Ball Feed, 1 Swift, Scotch Feed, 2 Swifts, Series Tape Condenser, 104 threads	390	J	50's Crossbred	13¼ ct. 10.36 sk.	14.50 ct. 11.32 sk.	13.20 ct. 1 .30 sk.	17.00 ct. 13.28 sk.	40	88.82	68	103	**4.02%**	**6.50%**
Breast and Swift, Ball Feed, 1 Swift, Scotch Feed, 2 Swifts, Single Ring Doffer, 52 threads	390	J	,,	13¼ ct. 10.36 sk.	14.34 ct. 11.20 sk.	12.10 ct. 9.46 sk.	16.86 ct. 3.17 sk.	40	100.00	79.5	123.5	**5.28%**	**7.07%**
2 Swifts, Ball Feed, 2 Swifts, Ball Feed, 1 Swift, Single Ring Doffer, 50 threads	200	K	Cashmere and Wool	24 ct. 18.75 sk.	23.45 ct. 18.32 sk.	18.70 ct. 14.60 sk.	27.00 ct. 21.10 sk.	75	50.02	33	66.5	**5.81%**	**12%04%**
Scribbler and Intermediate ditto, Ball Feed, 1 Swift, Single Ring Doffer, 75 threads	225	K	,,	36 ct. 28.1 sk.	33.83 ct. 28.46 sk.	28.00 ct. 21.86 sk.	38.54 ct. 30.10 sk.	56	39.37	30.5	57	**5.57%**	**10.12%**

It will be observed that the coefficient of variation of *strength* is always greater than that of *weight*. This is exactly what would be expected; for although the strength of a yarn depends principally upon the weight of material, it also depends on the twist, and on thick or thin places which may be due to any defective action of the mule or carder or condenser.

It will be seen that the coefficients of variation of *weight* range from 2.93% to 5.92% with an average value of 4.46%. The coefficients for the strength have range from 5.72% to 1.204% with an average of 8.28%. It is interesting to compare the corresponding figures from Publications No. 36 and No. 44. The figures are set out in Table B.

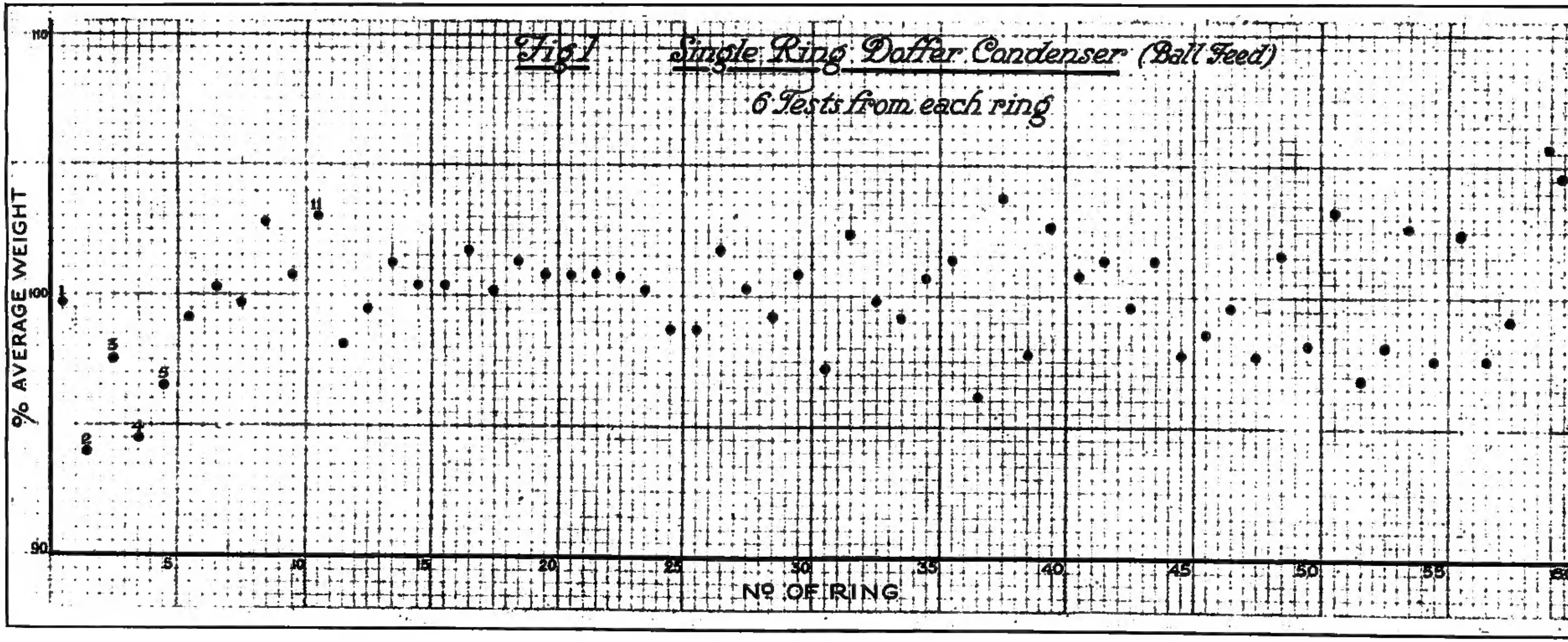
TABLE B.

Source of Result	Coefficient of Variation of Weight			Coefficient of Variation of Strength		
	Average	Least Value	Greatest Value	Average	Least Value	Greatest Value
Table A above :— 13 large samples of various woollen yarns	4.46%	2.93%	5.92%	8.28%	5.72%	12.04%
Table C. Publication 36 :— Small samples from 14 lots of 40's cross-bred Woollen Yarn 16 skeins	5.17%	3.29%	10.97%	8.43%	6.26%	14.41%
Table D. Publication 44 :— Small samples from 19 lots of 64's Flannel Yarn 33 skeins	4.04%	2.19%	6.21%	7.61%	3.86%	14.70%

This table shows that the average values and the ranges of the coefficients for the small samples of crossbred and flannel yarns, are similar to those for the large samples. It should be remembered, however, that great care was taken in the collection of the small samples to ensure that each part of the doffer was tested.

(Many carding engineers and spinners are content to weigh and test small quantities of slubbing and yarn from the middle of the condenser bobbins only, which is certainly not satisfactory).

Therefore it may be assumed that the small samples, correctly taken, gave results truly representative of the bulk lots. The figures



The diagram should be read as follows: (remembering that the average weight is 100):—
The weight of the yarn from No. 1 Ring is 99½ (that is ½% light); the yarn from No. 2 Ring is 94 (that is 6% light); from No. 3 Ring 97½ (2½% light); from No. 4 Ring 94½ (5½% light); from No. 5 Ring 96½ (3½% light); from No. 11 Ring 103 (3% heavy) and so on.

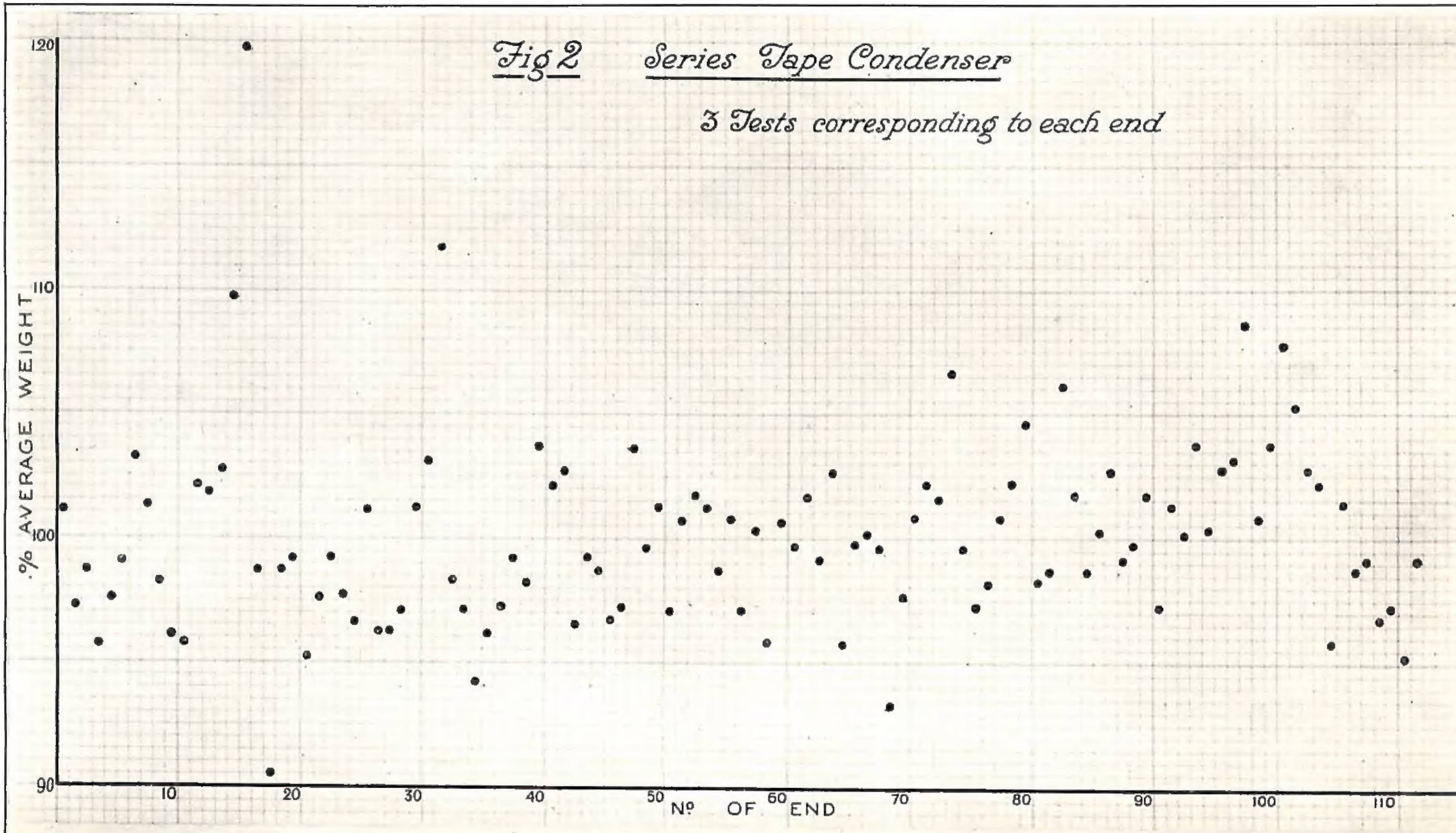


Fig 2
Series Tape Condenser
3 Tests corresponding to each end
% AVERAGE WEIGHT
120
110
100
90
10
20
30
40
50
60
70
80
90
100
110
Nº OF END

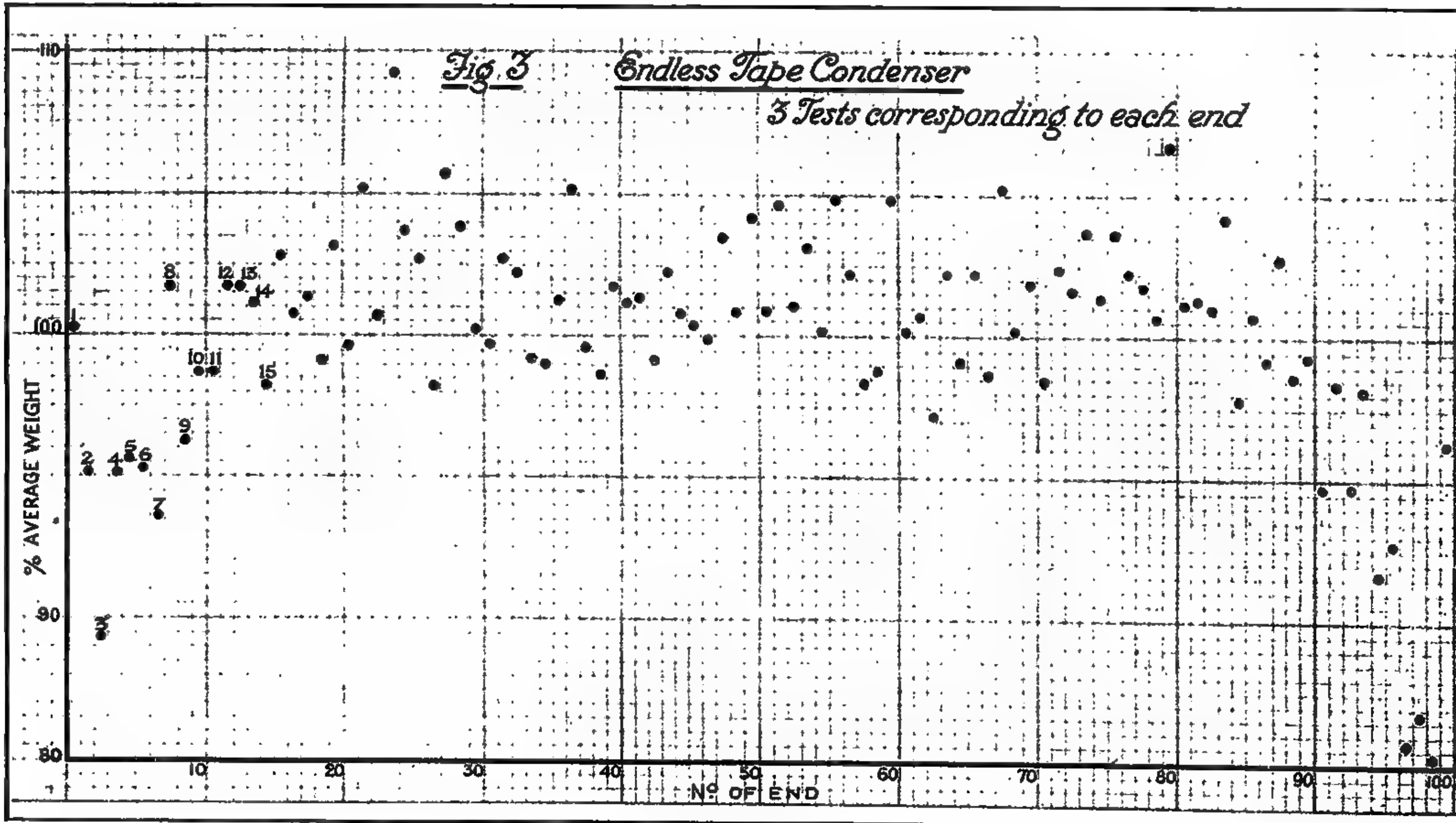


Fig. 3
Endless Tape Condenser
3 Tests corresponding to each end
110
100
90
80
% AVERAGE WEIGHT
10
20
30
40
50
60
70
80
90
100
Nº OF END

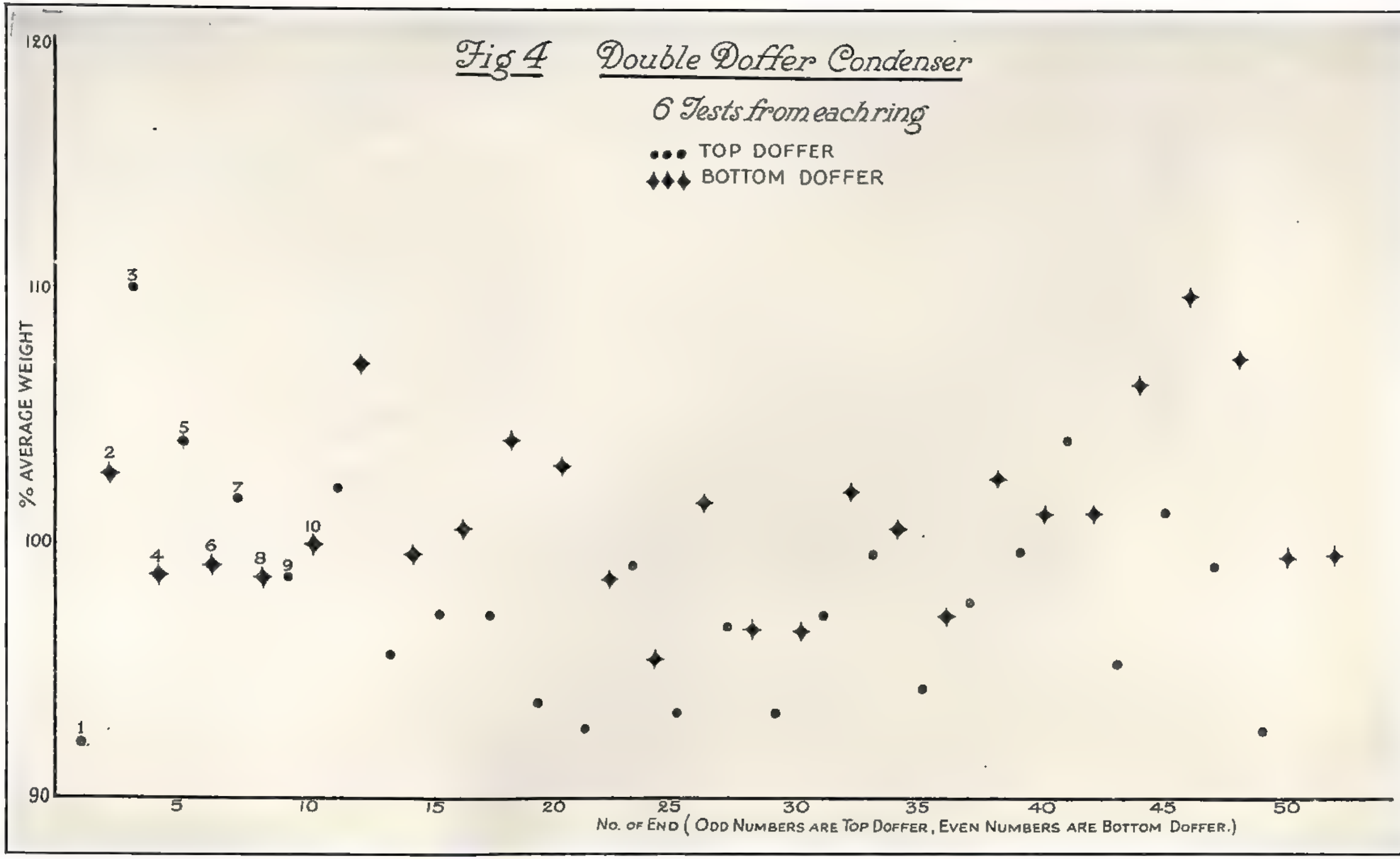


Fig 4 Double Doffer Condenser
6 Tests from each ring
TOP DOFFER
BOTTOM DOFFER
% AVERAGE WEIGHT
120
110
100
90
1
2
3
4
5
6
7
8
9
10
5
10
15
20
25
30
35
40
45
50
No. of End (Odd Numbers are Top Doffer, Even Numbers are Bottom Doffer.)

also seem to indicate that fine yarns are subject to somewhat smaller variations than coarser yarns.

Table C has been compiled in order to show whether the coefficients of variation are characteristic of the output of the mill. Assuming that a spinner does uniform work on the whole, similar values for the coefficients of variation would be expected from tests conducted at different times. The results indicate that there is some truth in this suggestion but that there are notable exceptions.

TABLE C.

Firm	Large scale tests from Table A		Tests on 64's Flannel blend 33 skeins. Table D. Pub. 44		Tests on 46's Crossbred blend 16 skeins. Table C. Pub. 36	
	Coeff. of variation of weight %	Coeff. of variation of strength %	Coeff. of variation of weight %	Coeff. of variation of strength %	Coeff. of variation of weight %	Coeff. of variation of strength %
J	4.02 5.28	6.50 7.07	3.59 4.00	7.98 6.35	3.74	6.93
H	2.93 3.65	5.72 6.16	5.74 3.66	7.61 7.92	—	—
C	4.15	5.86	3.72 2.24 2.19 4.71	5.78 3.86 5.35 4.64	—	—
F	5.92	8.25	—	—	5.23	9.53
D	4.11	10.24	3.87 6.21	10.70 14.70	—	—
B	4.22 4.09	8.35 7.96	—	—	5.78 4.62 4.13	7.28 7.29 6.42

The more detailed analysis of some of the results discloses some interesting facts. As examples, four sets of results from Table A are taken. These are :—

(1) Firm H. Direct Spun. The most regular set from the single ring doffer machines with ball feeds.

(2) Firm C. The most regular set from the series tape condenser machines.

(3) Firm D. A regular set from an endless tape condenser machine.

(4) Firm F. A set from a double doffer machine. This example though irregular is more regular than that of firm D. As, however, only two double ring doffers were tested no general conclusions can be drawn that this type is inferior.

The results were set out according to the position of the slubbing on the condenser. Thus in the case of the single ring doffer machine we had in the mule doffing six cops of yarn, which had all come from the same ring of the condenser (60 ends on the ring doffer and 360 spindles on the mule). Similarly for the series tape condenser there were three cops of yarn on the mule corresponding to each tape and for the endless tape three cops corresponding to each end delivered by the condenser. For the double doffer there were six cops corresponding to each end from the condenser.

Diagrams have been used to show the results since in this way the whole may be seen at a glance. We will take as an example the single ring doffer machine with ball feeds. The average weight of the hanks from all the 360 bobbins is first found. The figures for the cops from each separate end delivered by the condenser are then calculated. These are then reckoned as a percentage of the average of the 360 bobbins. Diagrams 1, 2, 3, and 4 show the results.

Fig. 1 exhibits the results from a remarkably even set. On reference to Table A, it will be seen that the carding engine has ball feeds and no waste threads. The ends at one extremity of the condenser are however definitely heavier than at the other. Fig. 2 shows some wide variations between the 15th, 16th, 17th and 18th ends and again at the 32nd. The most noticeable feature of Fig. 3 is the falling off in weight at both ends of the condenser. This may be due to draught. Apart from these special features the variations are distinctly large and emphasize the need for care in reeling all the ends, which is not often done by the average carding engineer and spinner.

It must not be assumed that the variations thus exhibited are due wholly to the condenser. If the film of wool on the last swift of the carder is not uniform the condenser cannot be expected to remove the irregularities.

The above work deals with weight and strength only. Variations in twist have not been investigated on so extensive a scale. Some idea of the extent of the variation in twist from bobbin to bobbin may be gathered from the results of an experiment conducted with a different object in view. A single condenser bobbin was put in the mule and four lots of yarn of 13½ skeins count were spun with various twist wheels.

The 26 bobbins in each set were then tested for twist with the following results :

COEFFICIENT OF VARIATION OF TWIST

13½ SKEINS WOOLLEN YARN.

Twist Wheel	No. of bobbins tested	Average Twist Turns per inch	Least Twist Turns per inch	Greatest Twist Turns per inch	Coefficient of Variation
44	26	7.48	7.32	7.64	1.33%
48	26	8.21	7.94	8.51	1.86%
52	26	8.75	8.25	8.99	2.24%
56	26	9.55	8.55	9.93	3.01%

For the method of measurement of twist by twist tester for single woollen yarns reference may be made to Publication No. 49. The average value of the four coefficients of variation is 2.11%. This may be taken as a representative figure, since it includes values of the turns per inch less than the normal as well as greater than the normal for yarn of 13½ skeins.

APPENDIX.

Coefficient of Variation.

In this paper on the normal variations of woollen yarns, the measure employed is the coefficient of variation. For the benefit of those unfamiliar with this, the following illustration of its meaning and calculation are given.

Let us suppose that in comparing two yarns A and B the following are the results of the strength tests :—

(A)	20 tests.	Strength in ozs.	6, 7, 8, 8, 9, 9, 9, 10, 10, 10, 10, 10, 10, 11, 11, 11, 12, 12, 13, 14. Total 200.	Average 10.0
(B)	20 tests.	,, ,,	6, 6, 6, 7, 7, 8, 9, 9, 10, 10, 10, 10, 11, 11, 12, 13, 13, 14, 14, 14. Total 200.	Average 10.0

In each case the average value is 10.0 ozs. but everyone would admit that A is the better yarn, since it has fewer very weak or very strong tests than B, in other words, the tests are more closely grouped about the average. These examples show at once that the greatest and least values of the strength afford no real test as to the quality of a yarn.

The actual calculation of the coefficients of variation in A and B affords the simplest explanation of their meaning. The calculations are shown in the table below.

	A			B	
1 Individual Tests	2 Difference from average	3 Square of difference from average	1 Individual Tests	2 Difference from average	3 Square of difference from average
6 ozs.	—4 ozs.	16	6 ozs.	—4 ozs.	16
7	—3	9	6	—4	16
8	—2	4	6	—4	16
8	—2	4	7	—3	9
9	—1	1	7	—3	9
9	—1	1	8	—2	4
9	—1	1	9	—1	1
10	0	0	9	—1	1
10	0	0	10	0	0
10	0	0	10	0	0
10	0	0	10	0	0
10	0	0	10	0	0
10	0	0	11	+1	1
11	+1	1	11	+1	1
11	+1	1	12	+2	4
11	+1	1	13	+3	9
12	+2	4	13	+3	9
12	+2	4	14	+4	16
13	+3	9	14	+4	16
14	+4	16	14	+4	16
Total 200	28	72	200	44	144
Average 10.0	1.40 Average difference from the average	3.60	10.0	2.20 Average difference from the average	7.20
Square Root	—	1.90 (Standard deviation)	—	—	2.65 (Standard deviation)
Percentage average difference from the average	$\frac{1.40}{10} \times 100 = 14.0\%$	—	—	$\frac{2.20 \times 100}{10} = 22.0\%$	—
Coefficient of variation = standard deviation as a percentage of the average	—	$\frac{1.90 \times 100}{10} = 19.0\%$	—	—	$\frac{2.65 \times 100}{10} = 26.5\%$

The individual tests are set out in the first column and the average value is found by adding the results of all the tests and dividing by the number of tests. In the second column is found the difference between each individual test and the average of column 1.

If we ignore the signs of these differences (*i.e.*, the plus or minus signs indicating whether the results are above or below the average of column 1) we can add together all the differences and divide their total by the number of tests. This gives the average difference from the average value of the strength as obtained in column 1. Thus we see that though yarns A and B have the same greatest and least strengths the average of the differences in column 2 are 1.40 ozs. and 2.20 ozs. respectively or 14.0% and 22.0%. This method of estimating variation is therefore superior to that which merely considers the greatest, least and average strengths.

In the third column the differences from the average of column 1 are squared and added together. This total is divided by the number of tests and thus the average of the squares of the differences from the average of column 1 is found. The square root of this average of the squares (*i.e.*, the result from column 3) is defined as the *standard deviation*. If now the standard deviation is expressed as a percentage of the average of column 1 we obtain the *coefficient of variation*. The standard deviation of the tests on yarn A is the square root of 3.60 (written $\sqrt{3.60}$) i.e., 1.90 ozs. and that for yarn B is $\sqrt{7.20}$ or 2.65 ozs. The average value of column 1 being 10.0, the values 1.90 and 2.65 become 19.0% and 26.5 respectively. These therefore are the coefficients of variation for the series of tests A and B respectively.

It is stated in standard works on statistics that this method of calculation of results leads to the most sensitive measure of variation. Examples could be found between which the method of column 2 would not distinguish, though the method of column 3 would detect the more irregular set.

The coefficient of variation is also referred to in Publication No. 36, p. 33 and Publication No. 44, p. 8.

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